

WHAT IS CLAIMED IS:

1. A drive method for a piezoelectric actuator comprising an oscillator that oscillates due to the supply of a drive signal with a specific frequency to a piezoelectric element, and a contact section that is provided to the oscillator and comes into contact with the driven object, wherein

a detection signal for indicating the oscillating state of the oscillator is detected and the frequency of the drive signal sent to the piezoelectric element is controlled based on the detection signal and the drive signal, or based on the detection signal;

the amplitude of the detection signal is detected;

the amplitude and a standard amplitude value are compared; and

the frequency of the drive signal is controlled based on the results of this comparison.

2. The drive method for a piezoelectric actuator according to claim 1, wherein one of the two methods of controlling the frequency of the drive signal is a method for controlling the increase or decrease in the frequency of the drive signal, and the other method of control is a method for controlling the rate of change of the increase or decrease in the frequency of the drive signal.

3. The drive method for a piezoelectric actuator according to claim 2, wherein the frequency of the drive signal is increased or decreased based on the detection signal and the drive signal or based on the detection signal, and the rate of change of the increase or decrease in the frequency of the drive signal is controlled based on the results of comparing the amplitude and the standard amplitude value.

4. The drive method for a piezoelectric actuator according to claim 3, wherein the rate of change of the increase or decrease in the frequency of the drive signal is reduced when the amplitude and the standard amplitude value are compared and the amplitude is equal to or greater than the standard amplitude value, and the rate of change of the increase or decrease in the frequency of the drive signal is increased when the amplitude and the standard amplitude value are compared and the amplitude is less than the standard amplitude value.

5. The drive method for a piezoelectric actuator according to claim 1, wherein the phase difference between a detection signal outputted from the oscillator for indicating the oscillating state of the oscillator and the drive signal is detected, and the

frequency of a drive signal sent to the piezoelectric element is controlled based on the results of comparing the phase difference and the standard phase difference value;

the amplitude of the detection signal is detected;

the amplitude and the standard amplitude value are compared; and

the frequency of the drive signal is controlled based on the results of this comparison.

6. The drive method for a piezoelectric actuator according to claim 1, wherein a plurality of detection signals outputted from the oscillator for indicating the oscillating state of the oscillator is detected;

the phase difference between the plurality of detection signals is detected;

the frequency of a drive signal sent to the piezoelectric element is controlled based on the results of comparing the phase difference and the standard phase difference value;

the amplitude of at least one detection signal from among the detection signals is detected;

the amplitude and the standard amplitude value are compared; and

the frequency of the drive signal is controlled based on the results of this comparison.

7. The drive method for a piezoelectric actuator according to claim 1, wherein the oscillator oscillates in a first oscillation mode and a second oscillation mode due to the supply of a drive signal with a specific frequency to a piezoelectric element; and

the detection signal is a detection signal outputted from the oscillator for indicating the oscillating state in the first oscillation mode and/or the second oscillation mode.

8. A drive device for a piezoelectric actuator for supplying a drive signal to the piezoelectric element in a piezoelectric actuator having an oscillator that oscillates due to the supply of a drive signal with a specific frequency to a piezoelectric element, and a contact section that is provided to the oscillator and comes into contact with the driven object, said device comprising:

frequency control means for controlling the frequency of the drive signal; and

amplitude detection means for detecting the amplitude of the detection signal, wherein

the frequency control means detects a detection signal for indicating the oscillating state of the oscillator and controls the frequency of the drive signal based on the detection signal and the drive signal, or based on the detection signal;

the amplitude and a standard amplitude value are compared; and

the frequency of the drive signal is controlled based on the results of this comparison.

9. The drive device for a piezoelectric actuator according to claim 8, the frequency control means comprising:

frequency increase/decrease control means for controlling the increase or decrease in the frequency of the drive signal; and

frequency increase/decrease rate control means for controlling the rate of change of the increase or decrease in the frequency of the drive signal, wherein

either one of the frequency increase/decrease control means or frequency increase/decrease rate control means detects a detection signal for indicating the oscillating state of the oscillator and controls the frequency of the drive signal on the basis of the detection signal and the drive signal, or on the basis of the detection signal; and

the other one of the frequency increase/decrease control means or frequency increase/decrease rate control means compares the amplitude and the standard amplitude value and controls the frequency of the drive signal on the basis of the results of this comparison.

10. The drive device for a piezoelectric actuator according to claim 9, the frequency control means comprising:

frequency increase/decrease control means for increasing or decreasing the frequency of the drive signal on the basis of the detection signal and the drive signal, or on the basis of the detection signal; and

frequency increase/decrease rate control means for controlling the rate of change of the increase or decrease in the frequency of the drive signal on the basis of the results of comparing the amplitude and the standard amplitude value.

11. The drive device for a piezoelectric actuator according to claim 8, comprising:
phase difference detection means for detecting a detection signal that indicates the oscillating state of the oscillator and detecting the phase difference between the detection signal and the drive signal or the phase difference between a plurality of detection signals, wherein

the frequency control means compares the phase difference detected by the phase difference detection means with the standard phase difference value and controls the frequency of the drive signal sent to the piezoelectric element on the basis of the results of

this comparison, and also compares the amplitude and the standard amplitude value and controls the frequency of the drive signal on the basis of the results of this comparison.

12. The drive device for a piezoelectric actuator according to claim 11, wherein the phase difference detection means is a phase difference/voltage conversion circuit that detects the phase difference and outputs a phase difference voltage signal whose voltage value corresponds to the phase difference.

13. The drive device for a piezoelectric actuator according to claim 12, the frequency control means comprising:

- a constant voltage circuit for outputting a standard voltage for comparing the phase difference and a standard voltage for detecting amplitude;

- a comparison circuit that compares the standard voltage for phase comparison outputted by the constant voltage circuit with the phase difference voltage outputted from the phase difference/voltage conversion circuit, and outputs a comparison result signal; and

- a drive control section that receives the comparison result signal outputted by the comparison circuit and controls the frequency of the drive signal sent to the piezoelectric element, wherein

- the amplitude detection device is an amplitude detection circuit that detects amplitude by comparing the standard voltage for amplitude detection outputted by the constant voltage circuit with the detection signal; and

- the drive control section has functions for decreasing the rate of change in frequency over a specific period of time when the amplitude detection voltage detected by the amplitude detection circuit is equal to greater than the standard voltage, and increasing the rate of change in frequency over a specific period of time when the amplitude detection voltage detected by the amplitude detection circuit is less than the standard voltage.

14. The drive device for a piezoelectric actuator according to claim 13, wherein the drive control section has a drive circuit for supplying a drive signal to the piezoelectric element, a voltage control oscillator for outputting a frequency corresponding to the voltage inputted to the drive circuit, and a voltage control circuit for adjusting the voltage supplied to the voltage control oscillator on the basis of the results of comparing the amplitude and the standard amplitude value.

15. The drive device for a piezoelectric actuator according to claim 14, the voltage adjustment circuit comprising:

a voltage adjustment section for adjusting the voltage outputted to the voltage control oscillator;

a clock circuit capable of varying the frequency of an outputted clock signal; and

a control circuit for outputting a signal to the voltage adjustment section according to the clock signal outputted by the clock circuit, and varying the frequency of the clock signal on the basis of the amplitude signal detected by the amplitude detection circuit.

16. The drive device for a piezoelectric actuator according to claim 15, wherein the control circuit slows the clock signal outputted from the clock circuit when the amplitude signal is equal to or greater than the standard voltage, and speeds up the clock signal outputted from the clock circuit when the amplitude signal is less than the standard voltage.

17. The drive device for a piezoelectric actuator according to claim 14, the voltage adjustment circuit comprising:

a loop filter that has different time constants and that outputs a voltage to the voltage control oscillator according to each of the time constants; and

a control circuit for selecting a time constant from the loop filter on the basis of the amplitude signal detected by the amplitude detection circuit.

18. The drive device for a piezoelectric actuator according to claim 17, wherein the control circuit decreases the amount of voltage outputted from the loop filter when the amplitude signal is equal to or greater than the standard voltage, and increases the amount of voltage outputted from the loop filter when the amplitude signal is less than the standard voltage.

19. An electronic timepiece, comprising:

a piezoelectric actuator having an oscillator that oscillates due to the supply of a drive signal with a specific frequency to a piezoelectric element, and a contact section that is provided to the oscillator and comes into contact with the driven object;

a drive device for the piezoelectric actuator according to claim 8; and

a date display mechanism driven by the piezoelectric actuator.

20. An electronic device, comprising:

a piezoelectric actuator having an oscillator that oscillates due to the supply of a drive signal with a specific frequency to a piezoelectric element, and a contact section that is provided to the oscillator and comes into contact with the driven object; and
a drive device for the piezoelectric actuator according to claim 8.

21. A control program for a drive device for a piezoelectric actuator for supplying a drive signal to the piezoelectric element in a piezoelectric actuator comprising:

an oscillator that oscillates due to the supply of a drive signal with a specific frequency to a piezoelectric element; and a contact section that is provided to the oscillator and comes into contact with the driven object, wherein

a computer incorporated into the drive device is made to function as:

amplitude detection means for detecting the amplitude of the detection signal; and

frequency control means that detects a detection signal for indicating the oscillating state of the oscillator and controls the frequency of the drive signal sent to the piezoelectric element on the basis of the detection signal or the detection signal and the drive signal, and compares the amplitude and the standard amplitude value and controls the frequency of the drive signal on the basis of the results of this comparison.

22. A storage medium capable of being read by a computer that stores the control program according to claim 21.